DOCUMENT RESUME

ED 350 557 CG 024 613

AUTHOR Novy, Diane M.; Francis, David J.
TITLE An Application of Hierarchical Linear Modeling to Group Research.
PUB DATE Aug 89
NOTE 18p.; Paper presented at the Annual Convention of the American Psychological Association (97th, New Orleans, LA, August 11-15, 1989).
PUB TYPE Reports - General (140)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Group Behavior; Group Counseling; *Groups; Individual Characteristics; Models; *Research
IDENTIFIERS *Hierarchical Linear Modeling

ABSTRACT

Hierarchical linear models distinguish between the individual and the group levels of data. Hence, they are often referred to as multilevel models. It is easiest to think of hierarchical linear models as special regression models that allow simultaneous investigation of the respective roles that individual and group characteristics play in the attainment of treatment goals. A hierarchical linear model can be fit to the data to investigate the contribution of individual characteristics to young people's end of treatment attainment and to determine how these relations are influenced by group characteristics. To simplify, people think of data as consisting of only two levels: individuals nested within treatment groups; and groups. The data are thus described by two models: the first model is based on individual data. It describes the prediction of individual outcome from individual characteristics and is referred to as the within-unity, or unit level mode. The second model expresses the variability in regression coefficients as a function of group-level variables. This model is referred to as the group-level, or between-unit mode. The majority of research studies on group therapy have ignored the group effect. Given the fact group characteristics are the prime reason for selecting this treatment modality, it appears important to include these characteristics in any model for treatment effectiveness. (ABL)

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An Application of Hierarchical Linear Modeling to Group Research

Diane M. Novy David J. Francis

University of Houston

Paper presented at the Annual Meeting of the
American Psychological Association
in New Orleans, LA August 1989

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An Application of Hierarchical Linear Modeling to Group Research

The purpose of this discussion is to introduce the group researcher to statistical methods better suited to the study of group process than traditional analysis of variance and multiple regression. These methods are known by the name hierarchical linear models. Hierarchical linear models distinguish between the individual and the group levels of data. Hence, they are often referred to as multilevel models. It is easiest to think of hierarchical linear models as special regression models that allow simultaneous investigation of the respective roles that individual and group characteristics play in the attainment of treatment goals. The particular individual characteristics of interest will depend on the nature of the treatment group. Group characteristics of interest typically pertain to leader qualities and contextual factors that describe the effects of the group members on one another.

Despite the nearly universal agreement that individual and group characteristics are important influences on individual outcomes, the literature does not reflect much empirical interest in individual characteristics and ignores group characteristics. The lack of empirical interest in group characteristics is at least partially due to the difficulty in using traditional statistical

methods to study hypotheses that are implicitly multilevel--i.e., when key independent variables, such as group characteristics, are typically measured at a higher level of aggregation than the outcome variable of interest (individual attainment on some attribute of interest).

Common individual characteristics such as gender and ethnicity have occasionally been included as factors in group outcome studies. These studies have used factorial analysis of variance, which permits the investigation of differential treatment effectiveness for classes of individuals with certain characteristics. By far the more frequently used procedure has been one-way analysis of variance, which simply permits the investigation of systematic differences among treatment means. Individual characteristics are treated as a nuisance, or source of error in the data. Studies using traditional analysis of variance techniques are typically characterized as a comparison between a treatment group and a control group, or between one therapeutic orientation versus an alternative one. Both designs ignore the fact that individuals may differ in their response to similar treatments as a consequence of the unique developmental ecology of each group in which the treatment is implemented. Traditionally, such individual and group-level variation is seen as a nuisance, in fact, the traditional definition of error variance implies that individuals within a group provide independent responses.

This assumption is usually untenable in group research where treatments are administered to groups of subjects. As a result, the standard error of the treatment effect will typically be underestimated, leading to overestimation of the statistical significance of treatment effects. Alternatively, the group instead of the individual can serve as a unit of analysis. Unfortunately, this strategy lacks power for detecting treatment differences. Moreover, it prevents differential treatment effectiveness for individuals with different characteristics. It also prevents the use of individual characteristics, such as pretest scores, as covariates. Since covariates can, in principle, dramatically enhance the statistical power of such a study (Porter & Raudenbush, 1987), this shortcoming is a serious one (Raudenbush & Bryk, 1988). In both the individual and group level approaches, the multilevel structure of the data is lost, i.e., neither analysis recognizes that individuals are nested within groups. Not surprisingly, the opportunity is also lost to investigate the dynamic interplay of individual and group characteristics in the attainment of treatment goals.

Failure to investigate the interaction of individual and group characteristics in the attainment of treatment goals has been cited as a serious shortcoming in an earlier review of group outcome studies (Bednar & Kaul, 1978). In general, this review suggests that although

research justifies group treatment, and provides a stimulus for further research, one must be aware of what is not being studied. Specifically many of the primary and unique variables of group treatment are not being subjected to empirical test.

The inability to adequately test the primary and unique variables of group treatment with traditional linear models has not prevented the conceptualization of these variables. Three noteworthy sources of information on the mechanisms of groups are Corsini and Rosenberg (1955), Hill (1957), and Yalom (1975). These works identify similar variables that may be subsumed within three higher-order concepts. First, group members may improve as a consequence of learning based on their participation in, and evaluation of, a developing social microcosm. Second, psychological growth may result from social learning processes based on interpersonal feedback and consensual validation. And third, individuals may profit from the reciprocal opportunities to be both helpers and helpees in group settings (Bednar & Kaul, 1978). Without an adequate methodology to test the validity of these concepts, the likelihood of any integrated understanding of the uniqueness of group treatments seem low.

The development of adequate computer software based on suitable mathematical models for data with a multilevel structure occurred in the mid 1980's. The reasons for

this development were concern about the inferences traditional methodologies yielded when data occur on more than one level, and the lack of compatibility in the conceptualization of multilevel data and the statistical analysis of these data.

Educational researchers (Aitkin & Longford, 1986; Goldstein, 1986,1987; Raudenbush & Bryk, 1986; Willms, 1987) who focus on the growth of student knowledge and skill occurring within educational organizations have been most active in analyses of multilevel data. The discussion and application of hierarchical linear models which follow are based on adapting innovations from educational research to group research.

Consider the following multi-level data from a group counseling situation. Therapy groups are formed at several juvenile probation departments for the purpose of enhancing juvenile offenders' level of social development. An individual measure of social development is obtained at the outset and termination of therapy. Offenders are assigned to weekly group counseling as a condition of their probationary status for a period of one year. The offenders differ in age and severity of the offenses committed. Measurements are made on group characteristics such as experience of the group leader, and the average interpersonal feedback provided from group members.

A hierarchical linear model can be fit to the data to investigate the contribution of individual characteristics

to young people's end of treatment attainment and to determine how these relations are influenced by group characteristics. To simplify, we think of the data as consisting of only two levels: individuals nested within treatment groups; and groups. The data are thus described by two models: the first model is based on individual data. It describes the prediction of individual outcome from individual characteristics and is referred to as the within-unit, or unit level model. In the context of the present example, this model states that post-test social development is predicted from pre-test social development, age of offender, and the severity of the committed offense. If one were simply studying individuals within a single group, standard regression techniques could be used to estimate the coefficients of this first equation. However, considering the multilevel structure of the data, it is reasonable to presume that the regression coefficients of the first equation vary across treatment groups. In fact, it is this variation which is of particular interest to group researchers. If groups play a role in individual outcome, then group characteristics will predict variation in the coefficients of model 1 across groups. As was stated before, the data from this example are described by two models. In fact, the second model expresses the variability in regression coefficients as a function of group-level variables. This model is referred to as the group-level, or between-unit model. In

this model, the parameters (intercepts and slopes) derived from the within-unit model for each group are expressed as a function of group characteristics. In the context of the present example, these characteristics are the experience of the group leader and the average interpersonal feedback provided by group members.

It is perhaps easiest to think of the two models as two separate stages in an analysis strategy. At the first stage, a regression analysis is performed in each treatment group separately. The coefficients from these analyses are saved and then become the dependent measures in the second stage of the analysis. In this latter stage, the estimated coefficients from the first stage are regressed on the group characteristics of leader experience and average interpersonal feedback from group members. While it is convenient to think of the analysis as consisting of two separate stages, in truth both models are fit simultaneously. To formalize our discussion somewhat, it is necessary to introduce some notation. The within-unit, individual level equation is:

$$Yij = B_{j0} + B_{j1}X_{ij1} + B_{j2}X_{ij2} + B_{j3}X_{ij3} + R_{ij}$$

where

Y_{ij} is the post-treatment social development score for individual i (i =1 ...nj) in group j (j = 1 ...k).

B_{j0} is the constant intercept for group j. B_{j0}

describes how well an individual with average individual pretest, age, and severity of offense performs on the social development posttest measure. In other words, B_{j0} is an estimate of the expected score in group j after controlling for variability in pretest score, age, and severity of offense at the level of the individual.

X_{ij1} represents the pretest social development score for individual i in group j.

B_{j1} is a regression coefficient that describes the effect of the pretest on the outcome measure of social development in group j, holding constant the effect of age and severity of offense.

X_{ij2} represents the age of individual i in group j.

B_{j2} is a regression coefficient for the effect of age on the outcome measure of social development in group j holding constant the effect of pretest and severity of offense.

X_{ij3} represents the severity of offense of individual i in group j.

B_{j3} is a regression coefficient for the effect of severity of offense on the outcome measure of social development in group j holding constant the effect of pretest and age.

R_{ij} is the unique contribution of individual i in group j. R_{ij} is the extent to which the outcome for subject i in group j is not fully explained by preceding

terms in the model.

From the previous description, we can see that it is the B_js (B_{j0}, B_{j1}, B_{j2}, B_{j3}) that are presumed to vary across groups, and that are to be predicted by the group-level characteristics. Because these parameters vary, they are known as random coefficients, or random effects.

The between-unit model is a system of equations based on the group level data; it is a model for the random coefficients from the within-unit model and is expressed as:

$$B_{j0} = O_{00} + O_{01}D_{1j} + O_{02}D_{2j} + U_{j0}$$

$$B_{jp} = O_{p0} + O_{p1}D_{1j} + O_{p2}D_{2j} + U_{jp}$$

where

B_{jp} is the pth coefficient from the unit level equation for group j. To make this more concrete, the between unit model will be described specifically for B_{j0}, the intercept of the within-unit equation.

B_{j0} is the intercept for group j from the within-unit equation. As such, it describes the expected post-test for an individual from group j with average pretest, age, and severity of offense.

O_{00} is the constant intercept from the group level model. Thus, O_{00} is the expected value of the unit level intercept (E_j (B_{j0}) when experience and interpersonal

feedback are held constant. Thus, θ_{00} represents the grand mean across groups in their adjusted level of performance.

D_{1j} is the score for leader experience in group j.

θ_{01} is a regression coefficient describing the effect of leader experience on expected group attainment, holding constant the effect of average group interpersonal feedback to others.

D_{2j} is the average interpersonal feedback score for group j.

θ_{02} is a regression coefficient describing the effect of average group interpersonal feedback on expected group attainment, holding constant leader experience.

U_{j0} is the unique contribution of group, i.e. U_{j0} describes the extent to which B_{j0} is not exactly reproduced by the group level model.

As mentioned, additional group-level regression equations are included in the between unit model. One equation is provided for each coefficient from the within-unit equation. This provides a multivariate formulation for examining the effects of between-group variables (*e.g.*, leader characteristics) on within-group relations (*e.g.*, the age-attainment relation).

This example was based on a data structure with two levels. It is possible to fit data with higher level structures. For example, it is possible that there are relevant differences across different juvenile probation

departments. Department could be incorporated as a third level in the model. In this case the structure of the data would be individuals within groups, groups within departments, and departments. Hierarchical linear modeling can also be used in group process studies. Here the data would be structured as time within individuals, individuals within groups, and groups. Once one has a multilevel mindset in regard to data, it is easy to see the complex structure of data that was previously conceptualized as single level.

The computational software for multilevel models is available from several groups of investigators (Bryk, Raudenbush, Seltzer, & Congdon, 1986; DeLeeuw & Kreft, 1986; Goldstein, 1986; Longford, 1987; Mason, Wong, & Entwisle, 1984). The statistical theories upon which these approaches are based and therefore the statistical properties of their results are, for most practical purposes, identical. All use iterative procedures to compute maximum likelihood estimates of variances and covariances. These estimates are computed by different numerical approaches which need not concern us here. Interested readers can see Raudenbush and Bryk (1988). The estimation procedures share five basic properties: 1) the effects of the sampling variance are minimized, 2) the covariation among the *B* coefficients are taken into account, 3) total variance in parameter estimates can be partitioned into true parameter variance and sampling

variance, 4) parameter covariation among the Bs is provided, and 5) the estimators of B_{jk} are corrected for unreliability.

As can be seen from this example and discussion, the implementation of hierarchical linear modeling greatly expands the range of methods for investigating groups. It also has the potential to extend conceptualization about relevant individual and group characteristics. It must be pointed out, however, that the design and data requirements to produce an adequate specification of the within-unit and between-unit equations are demanding. Identification of relevant individual and group characteristics is the first design requirement. A second requirement concerns obtaining a valid and reliable measure of attainment of the treatment goals at the individual level. Third, a pre-test measure should be built into the analysis to ensure that effects which any model may attribute to higher-level units, such as groups, are not simply a consequence of pre-existing differences among individuals within groups (Garner, 1989; Hauser, 1970). A fourth design point concerns sufficiently large samples at the group level to provide accurate estimates of group level parameters (Goldstein, 1987). Ideally, about 50 groups would provide that variation.

In summary, a methodology has been presented for the adequate assessment of the individual attainment of treatment goals that occur within groups. The majority of

previous research studies on group therapy have ignored the group effect. Given the fact that group characteristics are the prime reason for selecting this treatment modality, it appears important to include these characteristics in any model for treatment effectiveness.

References

Aitkin, M. A. & Longford, N. T. (1986). Statistical modeling issues in school effectiveness studies. Journal of the Royal Statistical Society, (Series A), 149, pp 1-26.

Bednar, R. L., & Kaul, T. J. (1978). Experiential group research: Current perspectives. In S. L. Garfield and A. E. Bergin (Eds.), Handbook of psychotherapy and behavior change. New York: John Wiley.

Bryk, A. S., Raudenbush, S. W., Seltzer, M., Congdon, R. T. (1986). An Introduction to HLM: Computer program and User's Guide. University of Chicago Department of Education.

Corsini, R. J., & Rosenberg, B. (1955). Mechanisms of group psychotherapy: Process and dynamics. Journal of Abnormal and Social Psychology, 51, 406-411.

DeLeeuw, J., & Kreft, I. (1986). Random coefficient models for multilevel analysis. Journal of Educational Statistics, 11,1, 57-85.

Garner, C. L. (1989). Educational attainment: A multi-level analysis of the influence of pupil ability, family, school and neighbourhood. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, Ca.

Goldstein, H. (1986). Multi-level mixed linear model analysis using iterative generalized least squares.

Biometrika, 73, pp 43-56.

Goldstein, H. (1987). Multi-level Models in Educational and Social Research. London: Oxford University Press.

Hauser, R. M. (1970). Context and consex: A cautionary tale. American Journal of Sociology, 75, 645-664.

Hill, W. F. (1957). Analysis of interviews of group therapists. Provo Papers 1.

Longford, N. T. (1987). A fast scoring algorithm for maximum likelihood estimation in unbalanced mixed models with nested effects. Biometrica, 74, 817-827.

Mason, W. M., Wong, G. Y., & Entwiste, B. (1984). Contextual analysis through the multi-level linear model. Sociological Methodology, San Francisco, CA: Jossey-Bass.

Porter, A. C. & Raudenbush, S. W. (1987). Analysis of covariance: its model and use in psychological research. Journal of Counseling Psychology, 34,4, 383-393.

Raudenbush, S. W. & Bryk, A. S. (1986). A hierarchical model for studying school effects. Sociology of Education, 59, 1-17.

Raudenbush, S. W. & Bryk, A. S. (1988). Methodological advances in studying effects of schools and classroom on student learning. In E. Z. Rothkopf (Ed.), Review of research in education, 15, 423-475.

Willms. J. D. (1987). Comparing schools on performance indicators: policy questions and data requirement.

Centre for Educational Sociology, University of Edinburgh, Edinburgh.

Yalom, I. (1975). The theory and practice of group psychotherapy. New York: Basic Books.